PATENT SPECIFICATION

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International Classification:—B02d. B01f. B02g. D21b.

COMPLETE SPECIFICATION

DRAWINGS ATTACHED

A Method and Apparatus for Continuously Changing the Structure of Substances or Mixtures of Such Substances

I, PETER WILLEMS, trading as Forschungsinstitut Professor Ing.-Chem. Peter Willems, of Steinhofhalde 20/22, Lucerne, Switzerland; stateless, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method and apparatus for continuously changing the structure of gaseous, liquid and/or solid substances or mixtures of such substances, for example of fibrous and elastic agglomerations and conglomerations of materials, by means of complexes of physical and kinematic effects, by subjecting the substances to vibrations at frequencies up to high supersonic frequencies, for dissolving, mixing, atomizing, disintegrating, decomposing, pulping, fibrising, homogenizing, refining, and for initiating and carrying out chemical reactions and processes of any kind.

Well known apparatuses for dispersing, homogenizing, decomposing, pulping and fibrising gaseous, liquid, solid and fibrous substances usually comprise relatively displaceable rigid disintegrating tools by which the substances are mechanically treated by shearing, bouncing, reflection and the like, whereby the substances to be treated are allowed to move along the shortest possible path in radial outward direction through the disintegrating tools.

The method according to this invention comprises distributing portions of the substances into a plurality of chambers disposed on a generally circular line, subjecting the substances while within said chambers to oscillations in a direction generally tangential to the circular line, transferring portions of said substances from said chambers into a plurality of further chambers radially spaced from said first chambers on a generally circular line substantially concentric with said first line, and subjecting said substances while within said further chambers to oscillations in a direction generally tangential to the second-mentioned line.

Apparatus according to the invention, suitable for carrying out this method, comprises a first plurality of chambers disposed on a generally circular line, a second plurality of chambers radially spaced from said first chambers on a generally circular line substantially concentric with said first line, the chambers within each plurality of chambers being separated by oscillatory members, and means for rotating at least one of the sets of chambers collectively about the common centre of the two lines.

In a preferred manner of carrying out this invention the substances are distributed into a rapidly increasing number of chambers by relative displacement of the chambers at a high velocity, whereby the particles of the substances are increasingly atomized. The particulars of reduced size obtained in this manner are pressed through the separate chambers of relatively small size (for instance 100 to 500 mm^3) under the action of overpressures varying pulsewise at high frequencies thereby overcoming counter pressures, the particles being thereby subjected to extremely high accelerations. The oscillatory pulsewise pressure variations acting on the particles contained in the treating chambers may be produced in accordance with the requirements of the substance or substances to be treated at frequencies in the audiofrequency range and in the supersonic frequency range. Preferably the particles are treated on their passage through the treating chambers during time intervals ranging from fractions of a second up to several seconds, so that every particle is subjected either in one particular treating chamber and/or

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ERRATA

SPECIFICATION NO. 891,152

Page 11, lines 121-122 and 129, page 12, lines 28 and 31, *for* "oscillators" *read* "oscillations"

Page 13, line 21, *for* "Fig. 5" *read* "Fig. 4"

Page 13, *after* line 22, *insert*

38. Apparatus for carrying out the method of any of claims 1 to 9, substantially as hereinbefore described with reference to, and as illustrated in, Fig. 5 of the accompanying drawings.

THE PATENT OFFICE,
27th August, 1962

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fibrising gaseous, liquid, solid and fibrous substances usually comprise relatively displaceable rigid disintegrating tools by which the substances are mechanically treated by shearing, bouncing, reflection and the like, whereby the substances to be treated are allowed to move along the shortest possible path in radial outward direction through the disintegrating tools.

The method according to this invention comprises distributing portions of the substances into a plurality of chambers disposed on a generally circular line, subjecting the substances while within said chambers to oscillations in a direction generally tangential to the circular line, transferring portions of said substances from said chambers into a plurality of further chambers radially spaced from said first chambers on a gener-

manner are pressed through the [illegible] chambers of relatively small size (for instance 100 to 500 mm^3) under the action of overpressures varying pulsewise at high frequencies thereby overcoming counter pressures, the particles being thereby subjected to extremely high accelerations. The oscillatory pulsewise pressure variations acting on the particles contained in the treating chambers may be produced in accordance with the requirements of the substance or substances to be treated at frequencies in the audiofrequency range and in the supersonic frequency range. Preferably the particles are treated on their passage through the treating chambers during time intervals ranging from fractions of a second up to several seconds, so that every particle is subjected either in one particular treating chamber and/or

when passing from one chamber to another to increasing frequency and increasing intensity of the oscillation and to increasing accelerations. The particles of the substance or substances treated in one particular chamber are released in the direction of the gradient of increasing pressure in the said particular chamber into another chamber through a slit, this slit being periodically opened for a short time interval. This slit and the duration of its open condition are so small that passage of a particle of the substance from one treating chamber to another is only possible subject to an increasing disintegration of the substance to particle sizes in the order of microns or less or until the individual fibres of a fibrous material, for instance cellulose, are separated from agglomerations. The production of pressure, acceleration, pulses and oscillations and feeding of the substances to be treated from one chamber to another are produced by a number of positive kinematic chains formed by the walls of the treating chambers and by the substance or substances treated in such chambers.

In addition to the primary audio or supersonic oscillations produced by the interaction of the edges of the oscillating members flying past each other, secondary pulses and waves are produced in the treating chambers by the adjacent vibrating oscillating members. Thus, interference waves are produced within the substances filling the treating chambers, the frequencies of such interference waves being a multiple of the frequency produced by the relative displacement of the oscillating members per se. When as set out above, the substances to be treated are practically enclosed in one chamber during a certain length of time instead of streaming through the kinematic system along the shortest possible path, the substances may be treated in the treating chambers to an extent not known and not possible with the treating methods and treating apparatuses known up to now.

Five embodiments of the apparatus for carrying out the method according to this invention are shown by way of example in the attached drawings in which

Fig. 1 is an axial section of the first embodiment having a horizontal generator shaft,

Fig. 2 is a view from the left in Fig. 1, partially in section along line II-II in Fig. 1,

Fig. 3 is a reproduction of a part of Fig. 2 on a larger scale,

Fig. 4 is an axial section of a second embodiment,

Fig. 5 is an axial section of a third embodiment,

Fig. 6 is an axial section of a fourth embodiment, and

Fig. 7 is an axial section of a multi-stage embodiment of this invention.

The generator shown in Figs. 1 to 3 is adapted for operation at high sound frequencies and supersonic frequencies and has a rotor 2 fixed on a horizontal shaft 1, the rotor having an inner annular row of members 3 for centrifugal acceleration of the substances to be treated, and three annular rows of oscillating members 4, 5 and 6 fixed on a ring disc 7 inserted into the rotor 2, the oscillating members consisting of steel, nickel, titanium, molybdenum, chromium or of alloys of such metals. Pairs of adjacent oscillating members 4, 5 and 6 enclose an acoustic treating chamber 8, 9 and 10 respectively between each other. The number of acoustic chambers (having a volume of say 100 to 500 mm³) increases in outward direction, and in the embodiment shown by way of example row 4 has 72, row 5 has 124 and row 6 has 180 acoustic chambers 8, 9 and 10 respectively. A conical member 30 fixed on shaft 1 enters into the hollow space 31, whereby a perfect filling and guiding of the substances to be treated are obtained in the space 31. The conical member 30 also prevents clogging of the hollow space 31. A collecting canal 13 surrounding the generator is attached to the casing of the generator by means of discs 14 and 15, this generator casing being mounted (in a manner not shown in detail) on a supporting structure 11. The disc 15 carries the stator 16 comprising four annular rows of oscillating members 17, 18, 19 and 20 respectively, such oscillating members being made of a material capable of oscillation, for instance one of the above mentioned metals or alloys thereof. The row of stator oscillating members 17 projects between the rows of rotor oscillating members 3 and 4, the row 18 of stator oscillating members projects between the rows of rotor oscillating members 4 and 5, and so on. On rotation of the rotor 2 the rows of rotor oscillating members closely fly past the rows of stator oscillating members. Each pair of adjacent oscillating members 17, 18, 19 and 20 encloses an acoustic treating chamber 21, 22, 23 and 24 respectively, having volumes of 100 to 500 mm³. In the embodiment shown by way of example in Figs. 1-3 row 17 has 60, row 18 has 90, row 19 has 168 and row 20 has 200 acoustic treating chambers. The distance between the surfaces of the stator and rotor carrying the oscillating members may be constant as shown in Fig. 2 or it may be variable in any desired way in order to obtain the same cross sections of the rows of oscillating members throughout the radial depth of the generator or cross sections varying in any desired manner over the radial depth of the generator. By way of example, the distance between the faces carrying the oscillating members may increase in radial

outward direction so that the volume of the acoustic chambers and the axial length of the oscillating members increase towards the periphery. Due to this increase in volume, tearing of the substances and increasing underpressure and consequently increasing cavitation are obtained when the substances are fed towards the periphery.

While in the embodiment of Figs. 1 to 3 the substances to be treated are sucked in and subjected to centrifugal acceleration by means of the members 3 disposed in the central chamber 31 of the generator, the substances being flung into the acoustic treating chambers under pressure and being disintegrated into fine particles, such feeding or pumping members 3 may be omitted and means located outside the generator, such as a pressure pump or a head of liquid upstream of the generator or a suction pump downstream of the generator may be provided. It is further possible that sufficient suction power is obtained by the action of the roating rows of oscillating members of the rotor without separate feeding and pumping members 3.

In order to obtain treating of the substances in a simple manner and in a continuous flow of the substances through the above described generator, whereby the substances are subjected to pulses and oscillations propagating in the treating space in the manner of waves, and in order to obtain easy control of the transit time of the substances through the sound-generator, an inlet or suction pipe 25 is connected to the ringshaped disc 15. The collecting canal 13 has an outlet piece 26 through which the substances flung from the acoustic treating chambers 14 into the canal 13 may continuously flow off, for instance into a pipe 27 or to any other place. Since the sound generator is mounted in a casing having an inlet pipe 25 and a collecting canal 13 with an outlet piece, it is possible to regulate in any desired way the flow velocity of the substances through the generator and the duration of treatment of the substances in the generator. By means of a regulating valve 28 arranged in the inlet pipe 25 the quantity of substances flowing into the generator per time unit, for instance per second, may be regulated as desired. A similar regulating valve 29 may be provided in the outlet piece 26 of the generator in order to regulate the flow velocity of the substances through the sound generator and for controlling the sound-treatment and pressure conditions in the generator and the duration of treatment of the substances in the acoustic chamber. Instead of the valve 28 and/or the valve 29 other suitable regulating means may be used, for instance a standpipe may be connected to the generator outlet instead of the valve 29, the standpipe opening into a container located at a level above the generator. The counter pressure thus produced in the standpipe may be adjusted to any desired value by providing a standpipe having outlet openings at different levels whereof the one may be opened for freely releasing the substances, whereas the other openings are closed. Instead of valves, iris diaphragms or variable-section pipe pieces may be inserted into the inlet or outlet pipe of the generator and all these means may be controlled manually or automatically.

Details of the generator shown in Figs. 1 to 3 may be changed in various ways. For instance, the peripheral surfaces of the members 3 and of the oscillating members 4 to 6 and 17 to 20 may be arranged on coaxial conical surfaces so that by relative axial displacement of the rotor and stator of the generator the gap width between the rows of oscillating members and chambers respectively may be varied. By adjusting the gap width to a very small value a rubbing and milling effect may be obtained in addition to the said acoustic irradiation, this being of particular use when treating fibrous materials. The radial distance between particular cooperating oscillating members of the stator and rotor or of groups of such oscillating members may be different so that some of the oscillating members rotating relatively to each other will provide for a milling and rubbing treatment whereas the remaining oscillating members will only be operative for feeding the substances. By this means a complex treatment similar to the one obtained with an edge or plug mill is obtained. The operation and effect of the generator may be changed within a wide range by particular design of the cooperating oscillating members. A shearing effect may be obtained by sharpening the edges of the cooperating oscillating members. If, on the other hand, such edges are rounded off a beating and bumping effect is obtained rather than a shearing effect. If the distance between cooperating oscillating members is very small a shearing effect is obtained with sharp edges whereas a crushing or compressing effect similar to the effect of an edge or plug mill is obtained with rounded edges. When the oscillating members are rounded off at their fore faces as seen in their rotating direction, or the oscillating members have a drop-shaped cross section with the rounding of the tip in the rotating direction. working of thixothropic or pasty substances. such as are encountered with high concentration cellulose deposits is substantially facilitated. As a result of numerous experiments it was found that by means of the apparatus according to this invention, for instance reducing of fibre bundles and shearing and/or milling, swelling and producing other

states of cellulose is possible up to very high concentrations of 10% and more. In order to obtain such favourable results not feasible with known apparatus. the generator is preferably so designed that the innermost row of oscillating members and acoustic chambers respectively has greater gaps or chambers between adjacent oscillating members, such particularly large chambers being able to take up the flocky or lump particles of the substance being fed from a coarse dissolver directly to the generator. The substance is accelerated by the oscillating members and is distributed under high pressure into the acoustic chambers of the next greater row of oscillating members and acoustic chambers respectively, whereby a relative displacement occurs between such adjacent rows. The outer row has an appreciable higher number of radial acoustic chambers. A further row of oscillating members and acoustic chambers respectively is displaced relatively to the last-mentioned row and outside the same, this further row having a still finer division, that is, having a still greater number of acoustic chambers. The number of concentric rows of oscillating members and acoustic chambers respectively may be increased as desired in order to obtain the required results and particularly the required degree of disintegration of the particles of substances to be treated. Since, in accordance with the increasingly finer division of the rows the oscillating members enclosing the acoustic chambers between each other become thinner towards the periphery of the generator, the natural frequency of such members, and more generally speaking the oscillating properties of such members, are different in different rows of oscillating members. The action of the oscillating member is comparable with that of a multiple tuning fork, the oscillating members being set to oscillation by the oscillating members of other rows flying closely past the oscillating members at a high relative velocity. The acoustic chambers between the oscillating members are similar to a whistle and more particularly a Galton pipe.

The apparatus has a great number of acoustic chambers and may therefore be compared with a Galton-organ, wherein the acoustic chambers of the different rows are arranged concentrically or approximately concentrically to each other and wherein the frequency varies from row to row in accordance with the dimensions of the oscillating members and their natural frequency and the width of the acoustic chambers. Therefore the substances when flowing pulsewise through the apparatus from the innermost row of oscillating members and acoustic chambers respectively outwards, are treated by pulses created by the meeting or crossing of the relatively displaced oscillating members and acoustic chambers of one row with the oscillating members and acoustic chambers respectively of an adjacent or two adjacent rows, the frequency of such pulses depending on the number of such meetings or crossings per time unit, for instance per second. These pulses are, as explained later on, of very high specific intensity and power. The intensity of the pulses depends in the first instance on the total energy applied to the sound-generator and on the number of and the distance between adjacent acoustic chambers of one and the same row of oscillating members and acoustic chambers respectively, and on the total number of oscillating members and acoustic chambers of the generator. Each row enclosing a smaller inner row of oscillating members and acoustic chambers and thinner oscillating members, produces an operating frequency of the pulses increasing from row to row and therefore an acoustic irradiation of the substances flowing through the apparatus at increasing frequencies is obtained. Preferably the subdivision of the rows into oscillating members and acoustic chamber is so designed in the outer rows of the apparatus that very high supersonic frequencies may be obtained as illustrated in the numerical example given below.

In this example the apparatus according to the invention has three rows R_1, R_2, R_3, of oscillating members and acoustic chambers respectively on the rotor and three similar rows St_1, St_2, St_3 on the stator, the numerical values being as follows:

	R_1	St_1	R_2	St_2	R_3	St_3
Inner diameter in mm	140	190	209	226	245	262
Outer diameter in mm	189	208	225	244	261	280
Outer circumference in mm	594	653	707	767	820	880
Number of acoustic chambers	6	60	72	90	124	168
Circumferencial width of acoustic chambers in mm		6	5	4	3	2.2
Circumferential thickness of the oscillating members in mm	12	4.88	4.82	4.52	3.6	3.04
Total cross section of chambers in cm^2		54	54	54	54	54
Frequency (kilocycles/second)		18	216	324	558	1041.6

Total number of chambers 520, Frequency 2,157,600. Speed n = 3000 revs./min.
Mean opening period of chambers: 1/600 sec.

For further explaining the physical effects occurring in the apparatus it may be stated that all these effects may occur simultaneously or that groups of such effects or single effects may occur at a time.

1) The acoustic irradiation of the substances in acoustic chambers:

The primary sound or supersonic oscillation produced by the meeting or crossing of the oscillating members of adjacent rows flying past each other at high velocity, propagate in radial direction in the coustic chambers which are substantially radially disposed round the axis of the apparatus, the frequency of the oscillations being determined by the frequency of successive meetings or crossings of oscillating members. In an aqueous liquid such oscillations are propogated at a velocity of about 1500 m/sec. Simultaneously, secondary waves of frequencies up to highest supersonic frequencies are produced in the acoustic chambers by the vibration of the oscillating members adjacent such acoustic chambers. Such secondary waves propagate transversely to the radial direction, that is in tangential or circumferential direction, through the acoustic chambers and through the substances contained in such chambers at a velocity in the order of 1500 m/sec., the frequency of such secondary waves being primarily determined by the natural frequency of the oscillating members. Thereby the sound waves emitted from the one oscillating member limiting an acoustic chamber are reflected by the other oscillating member limiting the same acoustic chamber. Thereby interference waves are set up in the acoustic treating chambers containing the substances to be treated, the frequency of such interference waves often being a multiple of the natural frequency of the oscillating members. The frequency of two secondary waves emitted by adjacent oscillating members limiting an acoustic chamber and propagating in opposite direction is increased by the crossing and interference of such waves, while the amplitude and consequently the energetic or specific effect of such interference waves decreases as the frequency increases. Of course the intensity of such secondary and interference waves also decreases due to absorbtion by the substances to be treated.

The number and the rotating speed of the oscillating members may be chosen in a manner that, in order to obtain maximum treatment of the substances by the pulses and oscillations occurring in the acoustic chambers, the substances are kept back in the chambers for a short time interval (for instance during 1/140 sec.) by the oscillating members flying past the chamber openings, or at least the radial acceleration of the substances is suddenly braked or broken whenever the substance flows over from one acoustic chamber to another one. In accordance with a duration of 1/140 sec. for which the substances are kept in the chambers, the opening period during which the substances are allowed to flow out of the chambers is of the order of 1/600 sec. Consequently the substances, when changing over from one chamber to another, are pulsewise pressed in extremely small quantities (of the order of one or several mgr at a time) into the next chamber, and are also pulsewise flung out of the chambers and are continuously further disintegrated. Thereby the accelerated column of substances is always broken by the oscillating members of the next outer row, and therefore the substances are not only subjected to the above mentioned pulses and oscillations within the chambers but the substances are further subjected to cavitation effects increasing with increasing diameter of the rows whenever flowing over from one chamber to another. By the temporary, at least partial, enclosing of the substances in a chamber limited by oscillating members constituting vibrating chamber walls, the substances only flow over into a chamber of the next outer row of oscillating members and acoustic chambers respectively after being transported over a certain circumferential distance in the said first chamber. Therefore, during their passage through the apparatus, the substances will be fed along a spiral consisting of stages 56 (Fig. 3), whereby the pitch of each stage corresponds to the radial advance of the particles contained in the chamber during one opening period of the chamber (that is in the example referred to above in the order of 1/600 sec.) whereas the peripheral advance of the particles in one chamber of the rotor is a function of the circumferencial velocity and of the radial advance of the substance per second, this radial advance being controlled by regulation of the inlet and/or outlet of the apparatus, as explained above.

With suitable choice of the total number of oscillating members and with sufficiently high rotating speeds acoustic frequencies of over 20,000 cycles/second, for instance frequencies of 1000 to 10.000 kilocycles/second may be obtained. Further, by proper choice of the number of chambers into which the substance flowing freely in from the central space 31 is distributed, and of the meeting or crossing frequency of the oscillating members and chambers respectively, extremely small primary particles of the substances of the order of a few milligrams, (for instance 1 to 5 mgr) may be produced, such particles being stepwise accelerated by the chambers along a spiral-shaped path and treated in the chambers by high frequency pulses. The oscillating members may be designed in such a manner that they are set into oscillation whenever meeting or crossing

an oscillating member of an adjacent row, the so-produced oscillations being radiated into the substances contained in the chambers limited by the oscillating member. The size of the acoustic chambers and of the oscillating members may be decreased preferably towards the periphery of the generator, and oscillating members having the form of needles attached to the carrying rings may be used. Of course, all the oscillatory members of the generator may be of the size of needles. It is further possible to use rows of such needles which are axially displaceable relatively to each other. The axial length of the oscillating members, particularly when needle-shaped members of very small cross section are used, may be very small. With oscillating members of the size of needles a disintegration of organic substances down to the size of the cellular structure thereof is possible.

At the exit of the generator the substances may be thrown into a space wherein the substances may further be treated by pulses and waves of different frequencies, this being particularly possible when the space has a hollow inner surface, being for instance of parabolic axial section. This hollow surface may be made of a material, for instance steel, having a suitable natural frequency so that maximum reflection of pulses and waves occurs on this hollow surface. For obtaining good reflection the surface may be worked very smoothly in order to form a mirror surface.

Due to the above-mentioned possibility of axial displacement between the stator and the rotor the gap width between the oscillating members flying past each other may for instance be adjusted in such a way that as an example cellulose fibers of much smaller size than the adjusted gap width are only acoustically irradiated in the manner described in the foregoing, but such cellulose fibres are not sheared and consequently not damaged. However, if shearing of the fibers is desired the gap width may be reduced to values near zero.

2) The kinematic treatment:

a) With every oscillation of two oscillating members one particle or a small quantity respectively of the substances flowing into the generator is pressed into an acoustic chamber of the next greater row of oscillating members and acoustic chambers respectively. Within each acoustic chamber the flowing velocity of the so sheared particles is suddenly substantially increased. Assuming for instance that the total section of the acoustic chambers is 1/3 of the total section of the row, the flow velocity of the particles flowing into a chamber is suddenly increased to three times its velocity between the rows of acoustic chambers. In practice, the flow velocity depends on the prescribed inlet and/or outlet velocity into and out of the apparatus respectively. This may be obtained in a simple manner by changing the flow section of the outlet, for instance by means of the regulating valve 29. Therefore, when the transit time of the substances for flowing through the apparatus is increased 10-fold by partially throttling the outlet section, the transit time of the substances for flowing through the individual acoustic chambers is also increased 10-fold, provided that the total width of the chambers remains constant, for instance 1/3 of the circumferencial length of the row of chambers. In accordance with this advancing velocity the volume of the particles produced may be calculated. The number of so produced particles equals the total frequency of the generator. With a total frequency of the apparatus of say 2,370,000 cycles/second (as is obtained in a numerical example set out below) and with a flow quantity of 40,000 liters per hour, a flow quantity of 11 liters or 11.000,000 mg per second is obtained, this quantity being first subdivided into particles having a mean weight of 4.6 mgr when the specific weight of the substance to be treated is 1.0. Each of these particles of 4.6 mgr will be treated by 853,200 pulses during its transit time of 0.36 seconds.

b) The bouncing effect, produced by the fact that the substances are thrown by the one oscillating members against the edge and the flanks meeting in this edge of the oscillating members of the next greater row of oscillating members and acoustic chambers respectively, causes a diffuse bouncing of the substances from the edge and flanks of the outer oscillating members. This diffuse bouncing effect depends on the combined action of the acceleration of the substances, the tangential component of acceleration being a linear function of the rotating speed whereas the radial component of acceleration increases with the second power of the rotating speed.

c) The multiple and diffuse reflection occurring due to the co-operation of the above mentioned kinematic actions causes a very intensive turbulence within the acoustic chambers, this turbulence allowing a most effective homogenizing of the different particles of the substances.

d) Due to the said multiple and diffuse reflection a very intensive interparticular and intermolecular friction is obtained, this friction resulting in an increase in temperature within the generator, provided that the duration of the treatment is sufficiently long. The interparticular and intermolecular friction particularly adds to the disintegration and to changes of the state of aggregation, and, possibly in combination with the heat produced by the friction, initiates and acceler-

ates desired chemical reactions. In this way catalytic or non-catalytic syntheses may be carried out easier, more rapidly and more homogeneously. However, the above-mentioned effects may also assist opposite reactions, for instance depolymerisation, and more generally speaking chemical changes of substances in different senses. The kinetics of reaction and the most suitable composition of the reagents for such chemical processes must be investigated from case to case.

In accordance with the requirements of the substances to be treated the flow section of the acoustic chambers, the thickness and the material of the oscillating members, the number of the latter per row, the number of treating stages that is, the number of rows of oscillating members and acoustic chambers respectively, the diameter of such rows and the rotating speed are adjusted. An increase of the distance between the oscillating members of one and the same row causes an increase of the volume of the acoustic chambers. Thereby the energy applied to the particular row of oscillating members and acoustic chambers respectively is increased, this resulting in an increase of the amplitude of the acoustic waves occurring in the chambers, but resulting also in a reduction of the operating frequency. It is further possible to radially or peripherally perforate all or some of the oscillating members, this measure resulting in a further very intensive oscillation produced by interference. Therefore, there are numerous possibilities of adjusting the kinematic effects directly acting on the structure of the substances to be treated, particularly on the solid components thereof, and also of adjusting the simultaneously acting acoustic irradiation of the material. As an example, a generator according to this invention comprising six rows of oscillating members and acoustic chambers respectively, viz: three rows on the rotor and three rows on the stator or on a second rotor rotating in opposite direction, was able to disintegrate to single fibres and to reduce the fibre bundles of a 5% cellulose in one single passage through the generator, the cellulose being previously dissolved in a pulper and containing 30 to 40% of fibre conglomerations. It was found that in the so obtained and disintegrated cellulose the fibers were practically not damaged and paper on card-board produced with the so prepared cellulose had a strength of more than 300% of products made of cellulose disintegrated with known methods. Other properties of the products so obtained are excellent. The energy required for treating the cellulose with the method of this invention was smaller than the energy required for carrying out similar known methods.

By accurate measurements it was found that the power dissipation of the generator according to this invention in the examples set out above and described hereinafter was of the order of 40 kW. This total power corresponds to a power dissipation of 84 W per oscillating member of the generator at a total operating frequency of 2,370,000 cycles/second. Such a specific power substantially exceeds the power dissipation of piezoelectric and magnetostrictive and other sound generators.

The embodiment shown in Fig. 4 differs from the apparatus shown in Figs. 1 to 3 substantially by the following features:

The generator has only two rows of oscillating members and acoustic chambers respectively on its rotor and stator, the rotor carrying rows 4 and 5 and the stator carrying rows 17 and 32. Row 32 consists of a ring having holes 33, the webs left between such holes constituting the oscillating members of row 32. Some of the oscillating members 4 of the rotor are equipped with knife-shaped extensions 34, but such extensions may be omitted when not required for the specific treatment. The extensions 34 shown in Fig. 4 cooperate with tools 35 attached to the suction tube 25, such tools having for instance the shape of cutting jaws, tooth-shaped, serrated or similarly shaped projections or of recesses. The tools allows a more intensive preliminary disintegration of the incoming substances than would be possible with the extensions 34 only. As indicated in dotted lines in Fig. 4 the suction tube 25 may generally be of smaller diameter and may be conically widened in front of the inlet opening of the sound generator in such a way that the incoming substances are fed into the operating range of the members 34 and 35. The explanations given above in connection with the embodiment of Figs. 1 to 3 similarly apply to the embodiment of Fig. 4. Apparatus as shown in Fig. 4 is particularly suitable for disintegrating lump substances, such a kaolin, or for rapidly saturating solid materials with binding materials and the like.

In the embodiment shown in Fig. 5 the driving shaft 1 is extended into the suction tube 25 through a conical hub 36 of the rotor 2, the extension of the driving shaft 1 carrying a pump rotor 37 having screw-shaped blades by which the substances to be treated are fed for instance from a container through the suction tube 25 to the sound generator. A stationary distributor 38 having guide vanes bent in a sense opposite to the bending of the blades of the pump rotor 37 is provided for improving the pumping effect of the pump. However, the distributor 38 may be omitted when sufficient pumping effect is obtained without it. Axi-

ally disposed guide baffles 39 are arranged at the inside of the suction tube 25, such guide baffles preventing or reducing rotation of the substances fed into the sound generator. However, such guide baffles 39 may also be omitted under particular circumstances. A propeller 40 is fixed at the free end of shaft 1 for when the greater pumping head or pressure has to be produced or when the substances are particularly difficult to feed because of their structure. The edges of the propeller blades may be sharpened so that they simultaneously cut and feed the substances.

In the embodiment of Fig. 5 the oscillating members 18 of the stator are webs clamped at both ends. The same explanations apply for this embodiment as given above in connection with the embodiment of Figs. 1 to 3.

The embodiment shown in Fig. 6 has two rotors 41 and 42 rotating in opposite directions instead of a stator cooperating with one single rotor. Rotor 41 is disposed on the suction side of the generator and is fixed on a driving shaft 44 rotatably mounted in the casing 43, whereas rotor 42 equipped with oscillating members 45 and 46 is fixed on a driving shaft 47 rotatably mounted in the casing 43 and adapted to be driven in a direction opposite to the rotation of shaft 44. A feeding and measuring worm 49 is fixed on shaft 44 and is disposed in the range of the suction tube 48. By proper choice of the pitch of this feeding and measuring worm the quantity of substance or substances flowing or pressed into the generator may be accurately adjusted. When, for example, the completely filled casing of the feeding worm contains 1 liter of a flowing substance and when the pitch of the worm equals one half of the axial length of the worm casing, half the contents of the worm casing, that is $\frac{1}{2}$ liter of the substance is fed to the generator for every full rotation of shaft 44. The feeding blades 53 of rotor 41, carrying the row 50 of oscillating members 51 and 52, impart to the entering substances a high circumferencial velocity in a direction opposite to the rotating direction of rotor 42. Therefore, the substance fed against rotor 42 by the blades 53 is first smashed on the oscillating members 45 and, according to the kind of the substance, is already disintegrated into coarse or fine particles. The further treatment in the generator is substantially as described in connection with the other embodiments. The treated substance discharged from the row 52 flows into the collecting canal 54 from where it is removed through the outlet pipe 55.

The four embodiments described above are adapted to operate with a horizontal, vertical or inclined rotating axis.

An example of the operation of the apparatus:

It is assumed in this example, that the acoustic irradiating apparatus has four concentric rows of oscillating members and acoustic treating chambers respectively. The innermost of the rows has 24 oscillating members and accordingly relatively wide treating chambers. The next row of oscillating members and treating chambers respectively, which is relatively rotated in opposite direction, has 100 oscillating members. The next row has 150 and the outermost and last row has 200 oscillating members. The peripheral thickness of the oscillating members and of the acoustic chambers differs in this embodiment from row to row and it is assumed that this thickness or width decreases from 10 mm at the innermost row to 2 mm at the outermost row of oscillating members and acoustic chambers respectively. The difference in rotating speed between the rotor and stator or two rotors respectively is assumed to be 3000 r/min. From these data a total frequency of the generator of

$$\frac{(24{,}100 + 100 \,.\, 150 + 150 \,.\, 200) \,.\, 3000}{60}$$

= 2,370,000 cycles/second is obtained.

This total frequency of the generator of 2370 kilocycles/second propagates throughout a liquid contained in the generator at a velocity of about 1500 m/sec. and in solid particles at a velocity of up to 4500 m/sec.

According to the kind of substances to be treated or to the power requirements, the oscillating members and acoustic chambers respectively may be distributed onto more or less rows of oscillating members and acoustic chambers respectively. Variations in the distribution of the oscillating members and chambers may also be due to constructive requirements or requirements concerning the general oscillating properties, and the distribution may for instance depend on the oscillating properties and on the material of the oscillating members. Thus, the same total number of oscillating members may be distributed onto six, eight, ten or more rows, whereby various divisions and various dimensions of the oscillating members and of the acoustic chambers are possible.

Example 1 of the method according to the invention[3]

11 liters per second or 40,000 liters of a substance per hour are fed through the apparatus described in the preceding example, continuous feeding of the substance being obtained by the centrifugal accelerating effect of the generator itself, and, whenever required, by the additional feeding effect of pumps disposed upstream or downstream of the generator, it being further possible to

regulate the flow in the whole flow system by manually or automatically operable or operating regulating devices.

The quantity of substance of 11,000,000 mgr per second flowing through the apparatus is treated with a total of 2,370,000 pulses corresponding to an acoustic irradiation at a frequency of 2,370,000 cycles/second. Since this high-frequency acoustic irradiation in the supersonic range is propagated through the liquid componets of the contents of the apparatus at a velocity of 1500 m/sec. and through the solid components of the substances at a velocity of up to 4500 m/sec. in all directions to the boundary surfaces of the space, that is the inner surfaces of the apparatus, each particle is acoustically irradiated at a frequency of 2,370,000 cycles/second. This clearly shows why mixtures having higher concentration of solid materials are treated more intensively and more perfectly than mixtures having a small content of solid material, because the velocity of propagation of acoustic waves in solid particles is about three times higher than in a liquid. Accordingly it was found by experiment that under similar treating conditions a 6% cellulose is better homogenized than a cellulose having a concentration of 2% only.

In the present example a mixture of kaolin and water having a concentration of 20% kaolin is fed through and treated in the apparatus at the above mentioned flow speed. The particle size of the kaolin ranges between 20 and 1 mm. The larger particles are reduced by shearing, bumping, smashing, friction and cavitation into still heterogeneous particles having maximum sizes of the order of millimeters, when such larger particles enter the inner row of oscillating members and acoustic chambers respectively, the division of such inner oscillating members and chambers being a relatively coarse one. Simultaneously the mixture of water and kaolin is subjected to the above described high-frequency acoustic irradiation occurring in the apparatus. Many experiments have shown that during the transit time of one second of the mixture through the apparatus the kaolin is homogeneously decomposed and suspended in the water at a particle size in the order of microns.

Example 2 of the method according to the invention:

Cellulose pulp, coarsely dissolved in water, obtained for instance from non-sorted waste paper and having a concentration of 5% is fed to the apparatus after dirt and metal particles have been removed, the feeding velocity being controlled by manual or automatic regulation of one or more regulating members. The cellulose pulp is thus subjected to the above described kinematic effects and to the acoustic irradiation.

The net volume of the casing of the apparatus after deduction of the volume of the active parts of the generator is four liters. Therefore, at any time, four liters of the coarsely dissolved cellulose are always contained in the generator and are subjected to the high-frequency kinematic effects and to the acoustic irradiation. The cellulose pulp is continuously fed to the apparatus in the form it is obtained from a dissolver, pulper or the like, whereby tubs, cleaners, concentrators and the like may be provided between the dissolver and the apparatus according to the invention. The flow speed is so adjusted that the contents of the apparatus are completely renewed in 0.36 seconds, that is that four liters per 0.36 sec. or 40,000 liters per hour are fed to the apparatus. In this manner, each particle, for instance each milligram, of the volume is treated by 853,200 pulses during its passage through the apparatus. Assuming that the particles of the substance first have the size of 1 mgr. each 853,200 acoustic pulses will also act on each separate particle during its passage through the apparatus, which corresponds to 2,370,000 acoustic pulses in one second. It was found by many experiments that during the transit time of 0.36 seconds of the substance the above mentioned particles, such as flakes, agglomerations of fibers, bundles or shives are completely disintegrated down to the obtention of single fibers and to the complete reduction of shives. If another degree of preliminary dissolution of the cellulose pulp or the resistance of the shives or bundles of fibers must be assumed, or when another degree of final disintegration, reduction of shives or bundles of fibers, milling effect, swelling or the like results is desired, the intensity of the treatment may be increased by repeating the treatment or by increasing the rotating speed of the apparatus, or the intensity of the treatment may be reduced or otherwise changed by reducing the rotating speed, by changing the radial gap between the rows of oscillating members and acoustic chambers respectively, such a variation of the gap width being possible by the well known measure of axially shifting the rows of oscillating members and acoustic chambers relatively to each other.

Example 3 of the method according to the invention:

This example stands generally for chemical reactions and is concerned with a reaction between a base and an acid whereby a gel or coagulation is formed simultaneously.

In accordance with this example production of silica for different well known purposes, such as a filler for collors, paper, rubber and so on or as a suspended or suspensible matter for increasing the stability of solutions emulsions and mixtures of various

kinds, is carried out as follows: An alkali metal silicate in liquid state, for instance one of the well known various kinds of water glass or soluble glass, of the required concentration is fed into the apparatus through the inlet pipe of the same. The liquid is sucked in by the suction of the generator, which may be assisted by an additional pump. At the inlet of the apparatus the admitted quantity of alkali metal silicate is controlled by means of a regulating valve and the flow may be measured when desired. Additional inlet pipes for feeding the necessary acid into the apparatus may be introduced into the casing through the axis of the main inlet pipe or at any other suitable place of the casing. Such additional inlet tube or tubes may be branched off in the interior of the apparatus, the delivery openings of the branches being near the central hollow space of the apparatus in order to obtain first intensive mixing of the agents by the way in which they are fed into the apparatus. When required the inlet pipes for the acid are also equipped with regulating and/or measuring instruments. After having set the apparatus to rotation equivalent quantities of the alkali silicate and of the acid are fed through their inlet pipes into the apparatus, the so admitted substances being immediately intensively and homogeneously distributed and smallest particles thereof are brought into close contact so that the desired chemical reaction and the formation of the silica immediately takes place. By the use of the method according to this invention silica may be obtained having any desired fineness and size of particles. Variation of these properties may be obtained in the well known manner by proper proportioning of the silicate and of the acid, such proportioning being possible by manual or automatic control of regulating members. The size of the particles may be adjusted to the desired value by adjusting the flow velocity in the generator. By suitable adjustment of the rotating speed of the rows of oscillating members and acoustic chambers respectively and of the transit time of the substances through the generator the required reduction of the spontaneously formed silica to extremely small particle sizes is possible. By the use of the method according to this example it is possible to control the physical and chemical structure of the silica discharged as a final product from the apparatus. Instead of acids suitable chemo-electrolytic active salts and other reagents for effecting precipitation of the silica may be used.

Further inlet pipes for adding further components, reagents, catalysts and the like of different state of aggregation for taking influence on physical or chemical effects within the apparatus may be arranged at suitable places of the casing of the apparatus, of the inlet and outlet pipes and at different suitable places and parts of the generator. Thus, gases may be added to liquids or mixtures treated in the generator for attacking such substances with gas or for producing foams. By introducing bases into the casing or into the generator acids or acid mixtures contained therein may spontaneously or latently be neutralized or their pH-factor may be adjusted. In a similar manner spontaneous or latent chemical reactions may be carried out at any desired intensity and under any desired control of the mechanism of the reaction by introducing additions into the casing of the apparatus or into the generator.

Of course the apparatus according to this invention may also be operated during longer or shorter time intervals at lower sound frequencies and it may also be used for shearing, smashing, reflecting, rubbing and other treatment of the goods.

Further, the design and shape and the dimensions of the apparatus and of parts thereof may be varied within wide limits in order to obtain desired operating characteristics, without departing from the general principle of this invention.

The rows of oscillating members may comprise prismatic, round, cylindrical or other shaped acoustic treating chambers of suitable size, when required of highest fineness and division, and the general direction or axis of such chambers may depart from the strictly radial direction. By these means similar effects as described above, such as pulses, acoustic waves, shearing, smashing, cavitation and so on may be obtained by the relative rotation of the rows of oscillating members and acoustic treating chambers respectively. Since it is possible in this way to obtain higher numbers and possibly different size of acoustic chambers, operating frequencies exceeding the above mentioned frequencies may be obtained. This makes it possible to further reduce the volume and weight of individual particles obtained by the treatment.

In order to obtain shearing, rubbing and possibly pan-grinding effects, which effects, when applied in the production of cellulose-pulp and similar or other mixtures, result in changes of structure, for instance swelling, changes in the water content of fibres or other particles, or in order to amplify or reduce such effects, the axial section of the relatively displaceable rows may be of conical, bell-shaped or terraced design so that the gap width between surrounding rows may be changed by relative axial displacement of such rows, the said gap width being adjustable from the highest technically required values to very small values for which latter shearing friction is obtained. The edges of at least some of the oscillating members and

the rubbing surfaces of the oscillating members of surrounding rows may further be toothed, serrated, roughened or provided with recesses in order to increase attack of certain substances to be treated in the generator. Further, the oscillating members of the rows may be corrugated, bent concavely or convexly and such oscillating members may be of highly elastic material. A high elasticity or resilience of the rows and oscillating members respectively may be obtained by the use or the addition of materials having high elasticity, such as rubber, plastic materials, spring metal or the like. In order to protect the inner surface of the apparatus, contacted by the substances to be treated therein, against abrasion or corrosion and similar effects, such surfaces may be covered with a hard or elastic, corrosion- and abrasion-proof protecting layer.

The apparatus according to this invention may also be designed as a multistage unit, this being for instance possible by adding one or more treating stages in axial direction to an apparatus as shown in Figs. 1 to 5. In this case, the substance or substances leaving the outermost stator row of the first stage are fed back towards the driving shaft into the central hollow space of the rotor of the following treating stage, it being possible to feed the substances from the first to the second stage by a flat or more or less conical guide disc closing the first stage on its side opposite the inlet for the substances. In such a multi-stage apparatus the substances may be subjected repeatedly to a similar treatment, it being possible to render the treatment in following stages more intensive than in preceding stages by suitable differences in the relative arrangement and design of the oscillating members and acoustic treating chambers. The substances may leave the peripheral row of oscillating members and acoustic chambers respectively of the last stage of the apparatus in radial, tangential or axial direction under the action of the pressure of the following substances. The discharge velocity and quantity of a multistage apparatus may be controlled in the manner described for the single stage apparatus, such as by provision of a discharge regulating valve or any suitable similar device.

The casing of each stage of the multi-stage apparatus may be equipped with a radial or tangential outlet, the outlet of each stage being adapted for individual or common regulation, whereby the outlets may completely be shut off. Thereby it is possible to treat a substance needing particularly intensive treatment in three stages put in series, the treated material being discharged from the third stage, and, without shutting down the apparatus it may be adapted for treating another substance requiring less intensive treatment by simply opening the outlet of the second or of the first stage and shutting off the outlets of the following stages so that the new substance is now treated in the first and second or only in the first stage of the apparatus, while the other stages are rendered inoperative by shutting their outlet valves.

Fig. 7 of the attached drawings shows, by way of example, an apparatus comprising three stages 57, 58 and 59 of generators having rows of oscillating members and acoustic chambers respectively. The above mentioned guide discs 60 are disposed between the stages. The flow of the substances through the multi-stage apparatus is indicated by the arrows P. A feeding and pressure worm 63 fixed near the left end of the driving shaft 61, is provided in the inlet 62 to the first stage of the apparatus.

In many industries, for instance in the cellulose producing industry, it has often been necessary to arrange two, three or more treating apparatuses of the same kind in series, the substance to be treated flowing successively through all of these apparatuses in order to be subjected to sufficient treatment, for instance decomposing, pulping, fibrising, refinement and so on. In general, feeding pumps and/or intermediate containers are required between successive treating apparatus. The multistage apparatus according to this invention allows such expensive treating plants to be omitted and at the same time allows an appreciable saving in energy and space, attendance of the apparatus is much simplified and the time saving may be in many cases of up to 90% as compared with the time required for treating the same quantity of the same substance in the same way with known treating plants.

While the invention has been described and illustrated with reference to specific embodiments thereof, it will be understood that other embodiments may be resorted to without departing from the invention. Therefore, the forms of the invention set out above should be considered as illustrative and not as limiting the scope of the following claims.

WHAT I CLAIM IS:—

1. A method of continuously changing the structure of gaseous, liquid and/or solid substances or mixtures of such substances, comprising distributing portions of the substances into a plurality of chambers disposed on a generally circular line, subjecting the substances while within said chambers to oscillators in a direction generally tangential to the circular line, transferring portions of said substances from said chambers into a plurality of further chambers radially spaced from said first chambers on a generally circular line substantially concentric with said first line, and subjecting said substances while within said further chambers to oscillators in a direction generally tangential to the

second-mentioned line.

2. A method as claimed in claim 1, in which the transferring of the substances from the first plurality of chambers into the second is effected by relative displacement of the first and second pluralities of chambers.

3. A method as claimed in claim 1 or claim 2, in which the second plurality of chambers consists of more chambers than the first.

4. A method as claimed in any of claims 1 to 3, in which the frequency of the oscillations is greater in said second plurality of chambers than in the first.

5. A method as claimed in any of claims 1 to 4, in which the transfer of substances from the first plurality of chambers to the second is effected through a slit which is periodically opened momentarily.

6. A method as claimed in any of claims 1 to 5, in which the total flow of the substances through the chambers is collectively controlled.

7. A method as claimed in any of claims 1 to 6, in which the chambers of at least one set are rotated collectively about the common centre of the substantially concentric lines and the intensity of the oscillators is varied by varying the speed of rotation.

8. A method as claimed in any of claims 1 to 6, in which the intensity of the oscillators is controlled by varying the gap between the first and second lines of chambers.

9. A method as claimed in any of claims 1 to 8, in which additives for reaction or admixture with said substances are introduced into contact with said substances during oscillation of the latter.

10. Apparatus for carrying out the method of any of claims 1 to 9, comprising a first plurality of chambers disposed on a generally circular line, a second plurality of chambers radially spaced from said first chambers on a generally circular line substantially concentric with said first line, the chambers within each plurality of chambers being separated by oscillatory members, and means for rotating at least one of the sets of chambers collectively about the common centre of the two lines.

11. Apparatus as claimed in claim 10, in which the second plurality of chambers consists of more chambers than the first.

12. Apparatus as claimed in claim 10 or claim 11, in which the second line is of greater diameter than the first.

13. Apparatus as claimed in claim 12, in which at least some of the oscillatory members are adapted to be set in oscillation by the passing of two members in different lines.

14. Apparatus as claimed in any of claims 10 to 13, having an outlet surrounded by a surface which reflects sound waves.

15. Apparatus as claimed in any of claims 12 to 14, having a suction-fed inlet and having a collecting channel surrounding the outermost line of chambers.

16. Apparatus as claimed in any of claims 10 to 15, having a manually or automatically operable flow regulator on the feed side of the apparatus.

17. Apparatus as claimed in any of claims 10 to 16, in which the different sets of oscillatory members are designed to oscillate at different frequencies.

18. Apparatus as claimed in any of claims 10 to 17, in which the rotary set of chambers carries knife-edged extensions cooperating with projections on, or recesses in, the stationary part of the apparatus.

19. Apparatus as claimed in any of claims 10 to 18, in which the spacing between the sets of chambers is variable.

20. Apparatus as claimed in claim 19, in which each set of chambers is disposed about a surface of varying diameter and the spacing between the sets of chambers is varied by relative axial displacement of the sets.

21. Apparatus as claimed in any of claims 10 to 20, in which the spacing between the sets of chambers is non-uniform.

22. Apparatus as claimed in any of claims 10 to 21, in which some of the chambers are separated by oscillatory members having sharpened leading edges.

23. Apparatus as claimed in any of claims 10 to 21, in which some of the chambers are separated by oscillatory members having rounded-off leading edges.

24. Apparatus as claimed in any of claims 10 to 21, in which some of the chambers are separated by oscillatory members having irregular, e.g. serrated, leading edges.

25. Apparatus as claimed in any one of claims 10 to 24, in which some of the chambers are separated by bent oscillatory members.

26. Apparatus as claimed in claim 25, in which the oscillatory members are corrugated.

27. Apparatus as claimed in any of claims 10 to 26, in which some of the chambers are separated by oscillatory members which are perforated.

28. Apparatus as claimed in any of claims 10 to 27, having an axially disposed conical member to guide the substances to be treated into the first set of chambers.

29. Apparatus as claimed in any of claims 10 to 28, fed by a pump rotor.

30. Apparatus as claimed in any of claims 10 to 28, fed by a screw conveyor.

31. Apparatus as claimed in any of claims 10 to 30, having a rotary propeller at the inlet side of the apparatus.

32. Apparatus as claimed in any of claims 10 to 31, having at least one subsidiary inlet for introducing additives for admixture or reaction with the substances to be treated.

33. Apparatus as claimed in claim 32,

having a regulating or measuring device in the subsidiary inlet.

34. Apparatus as claimed in any of claims 10 to 33, of which the parts coming into contact with the substances being treated are coated with an abrasion- or corrosion-resistant material.

35. Apparatus as claimed in any of claims 10 to 34, in which the total volume of the chambers in each set increases from the inlet side to the outlet side of the apparatus.

36. Apparatus for carrying out the method of any of claims 1 to 9, substantially as hereinbefore described with reference to, and as illustrated in, Figs. 1 to 3 of the accompanying drawings.

37. Apparatus for carrying out the method of any of claims 1 to 9, substantially as hereinbefore described with reference to, and as illustrated in Fig. 5 of the accompanying drawings.

39. Apparatus for carrying out the method of any of claims 1 to 9, substantially as hereinbefore described with reference to, and as illustrated in, Fig. 6 of the accompanying drawings.

40. Apparatus for carrying out the method of any of claims 1 to 9, substantially as hereinbefore described with reference to, and as illustrated in, Fig. 7 of the accompanying drawings.

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FIG.1

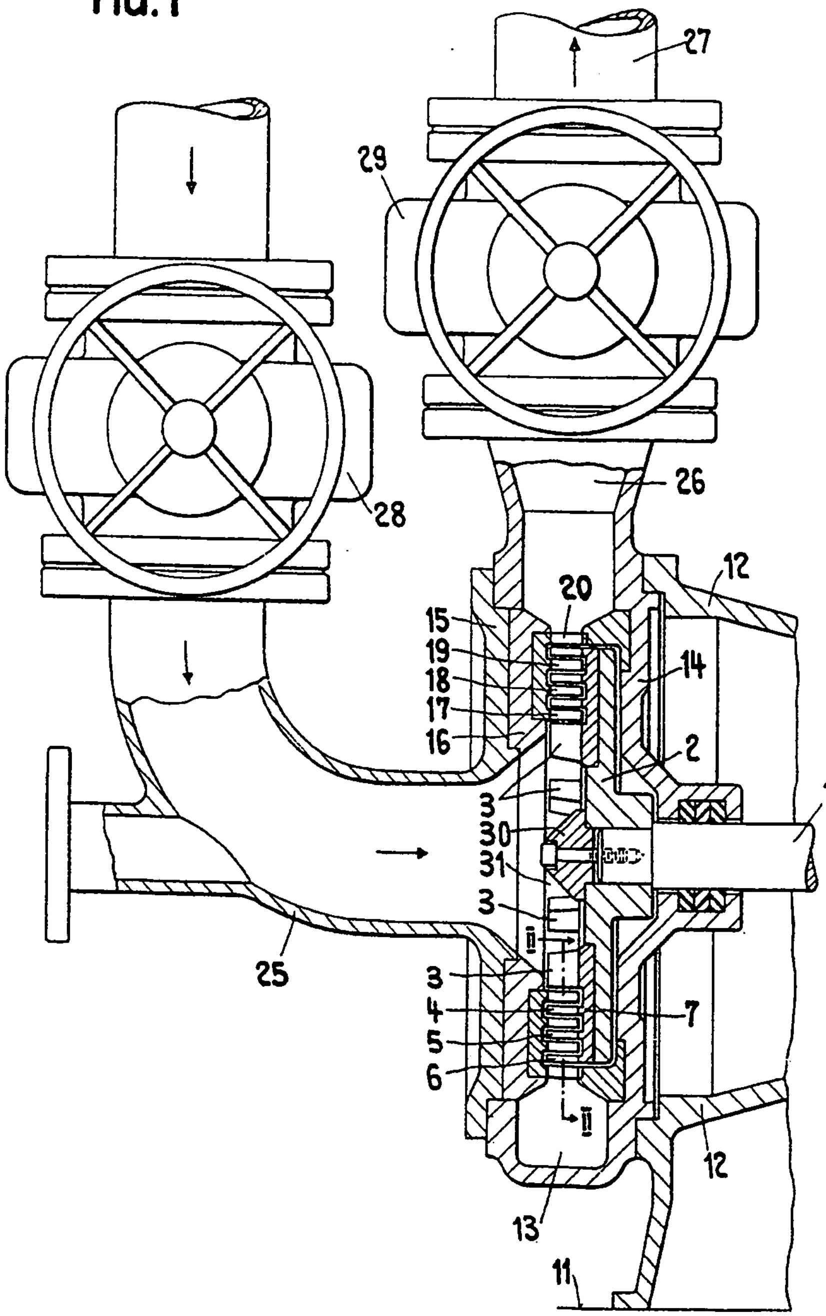


FIG.2

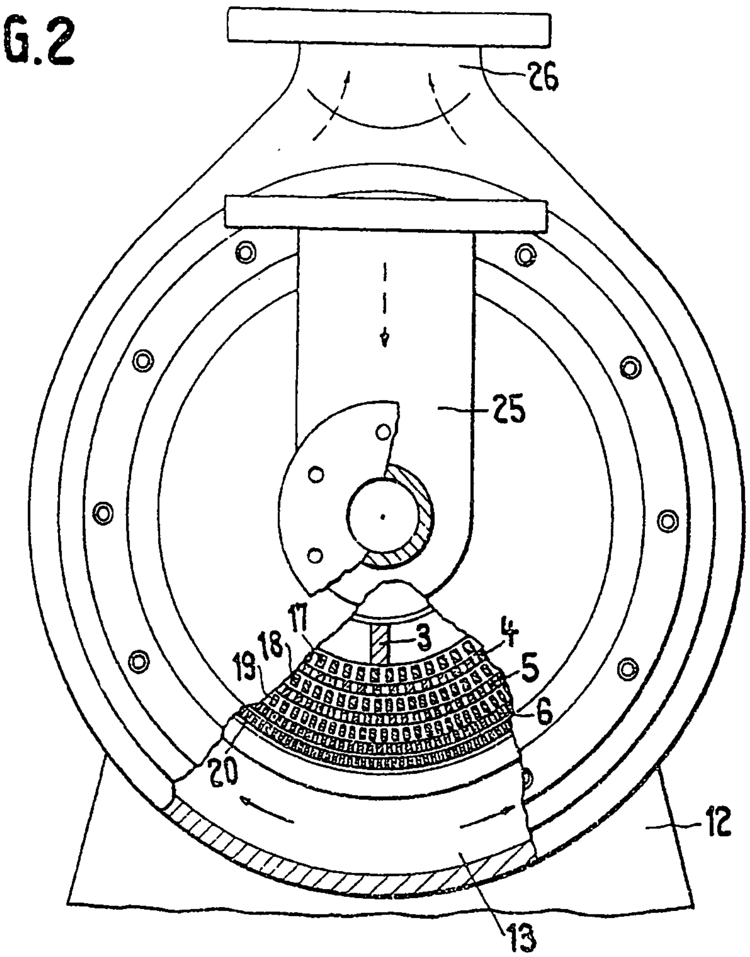
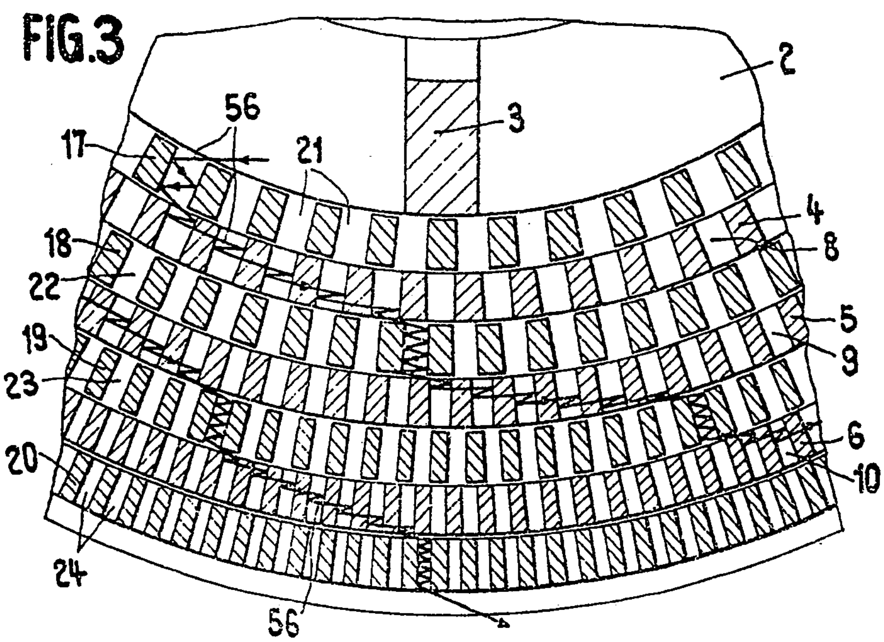


FIG.3



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SHEETS 2 & 3

FIG.4

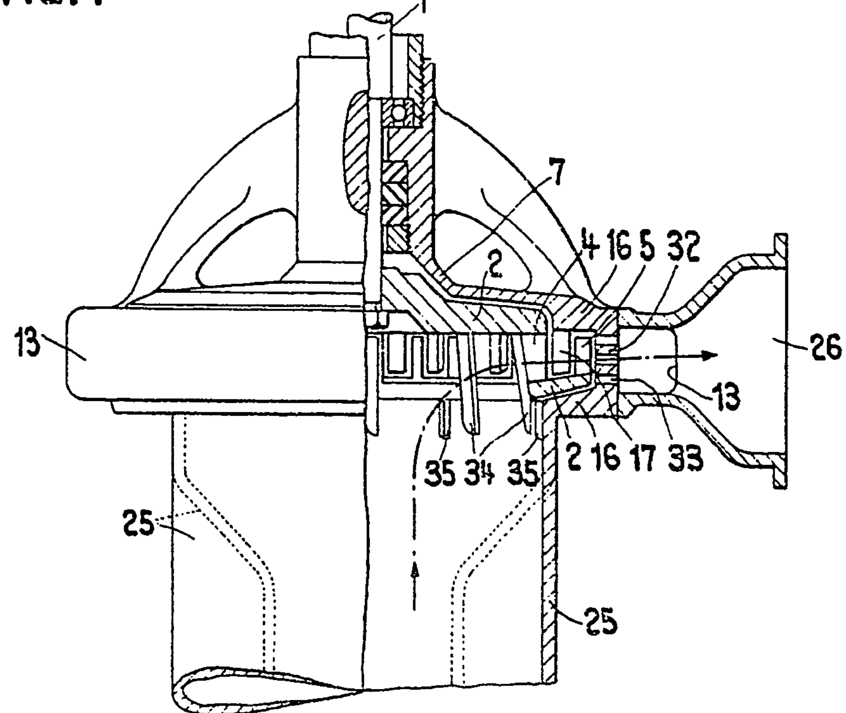

FIG.7

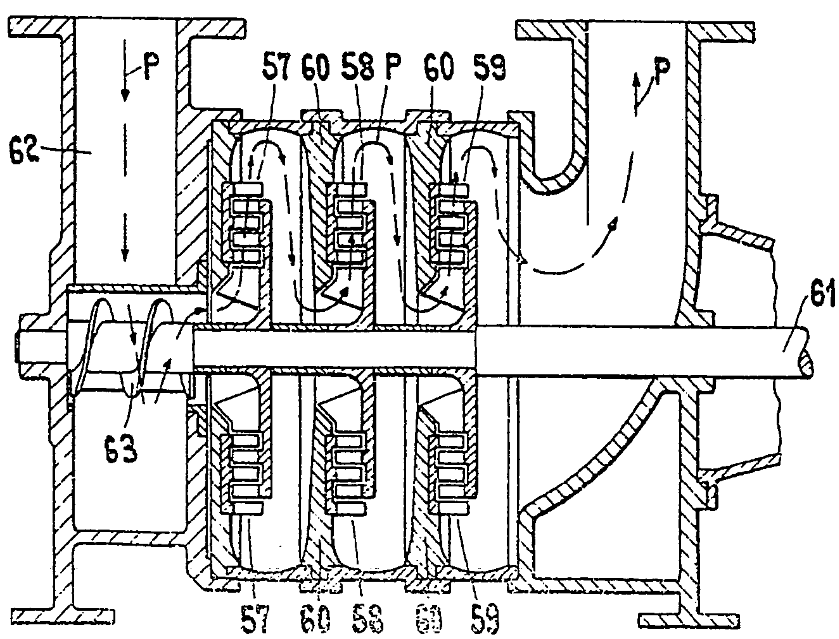

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FIG.2

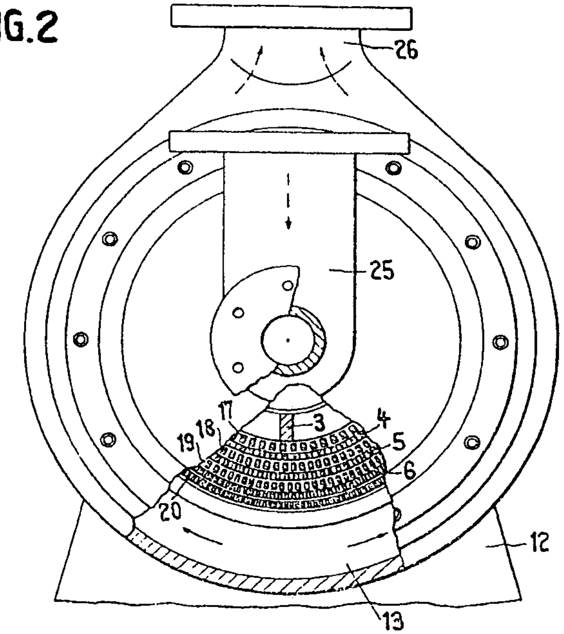
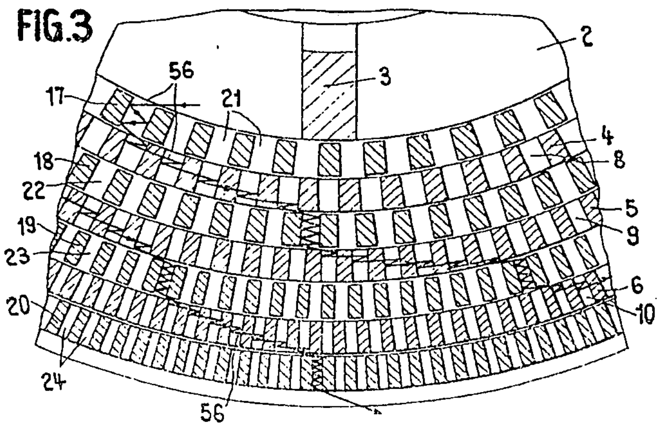


FIG.3



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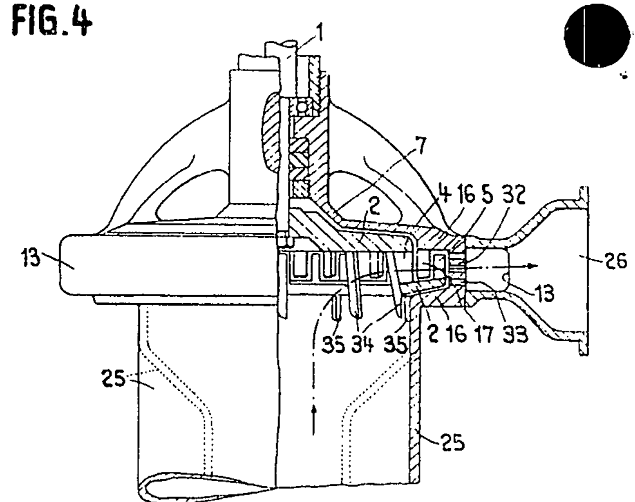

FIG.7

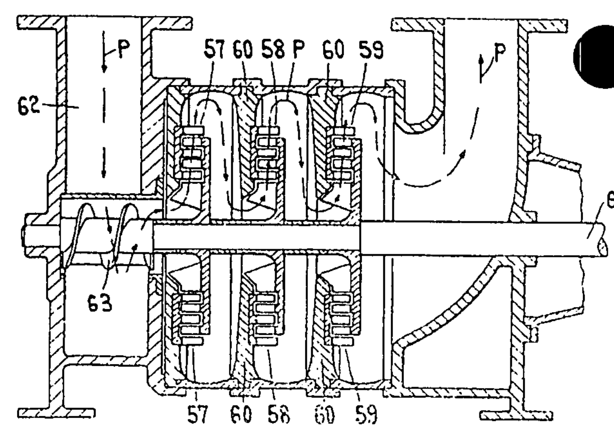

FIG.5

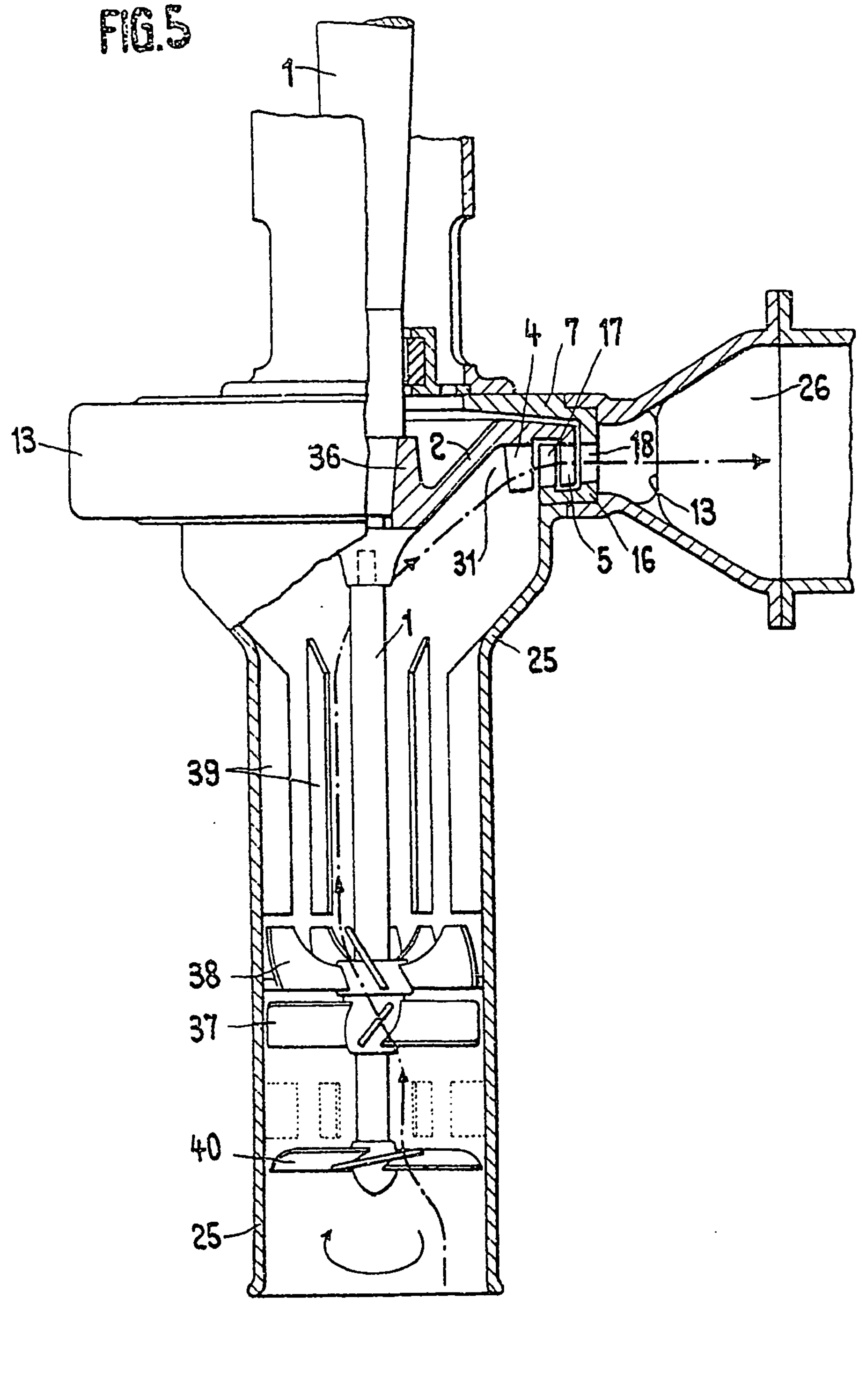

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FIG.6

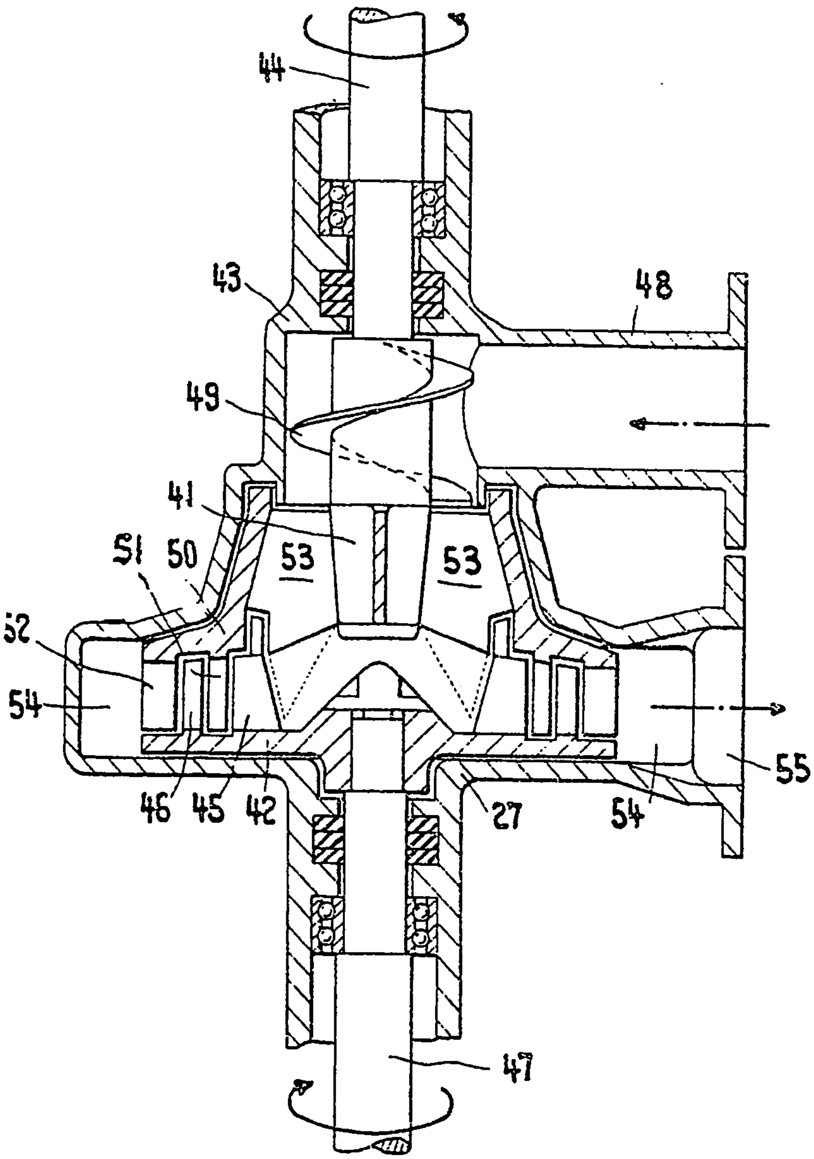

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FIG.5

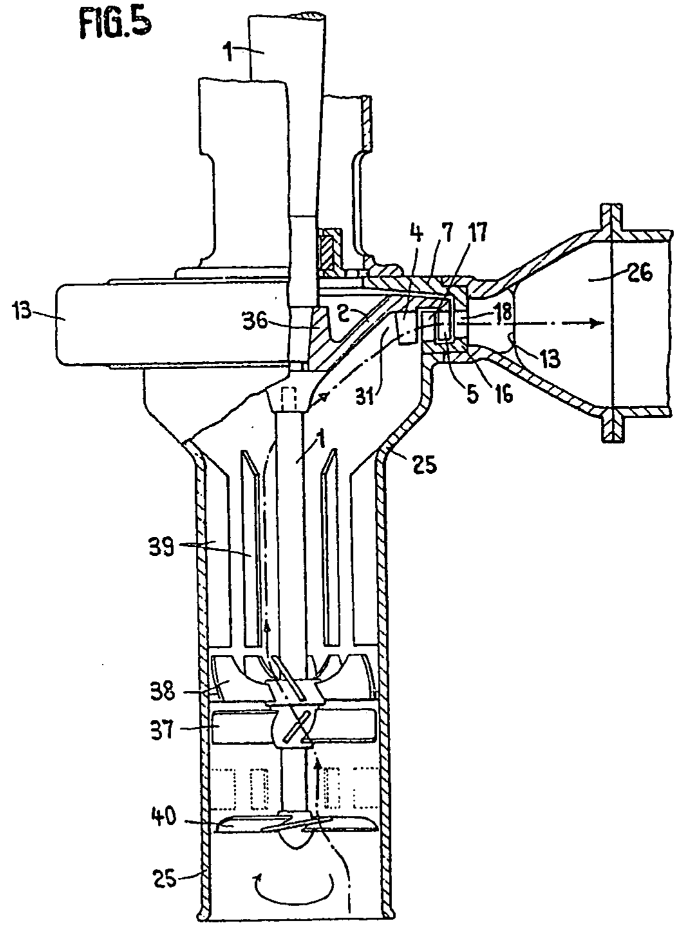

FIG.6